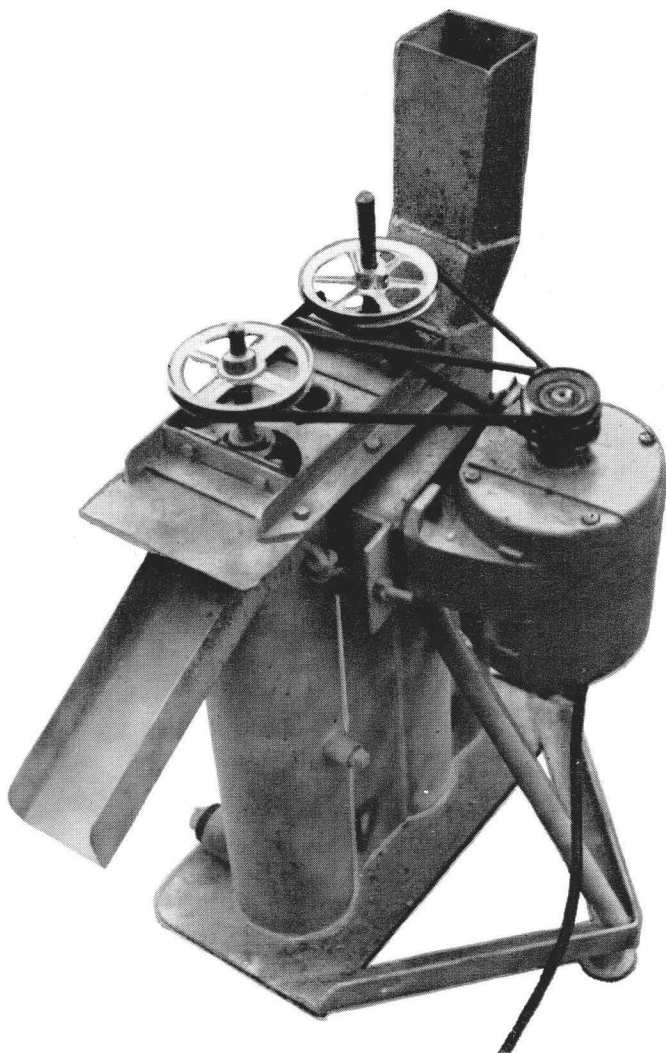


A NEW MECHANICAL COFFEE DEMUCILAGING MACHINE

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A NEW MECHANICAL COFFEE DEMUCILAGING MACHINE

By Edward T. Fukunaga

INTRODUCTION

The coffee cherry consists of the outer skin (epidermis), the fleshy pulp (pericarp), and two seeds (endosperm), called "beans" by the coffee trade, in the center of the cherry. These seeds are flat on one side and in each pair the flat sides face each other.

Each bean has two additional layers of protective matter. The layer directly in contact with the bean is very thin and papery and it is called silver skin (perisperm). Outside this silver skin is a tough parchment-like matter (spermoderm) commonly called parchment. In the fresh state the parchment is coated with a thick layer of slimy gel-like substance (mesocarp) commonly called mucilage. The dried coffee bean or seed with all of its coverings removed is called green coffee by the coffee trade. This green coffee is roasted and ground to make the retail product.

The principal objective in processing coffee at the grower level is the dehydration of the coffee bean to a point where all biological actions cease and further processing to the green coffee stage is possible. At this stage, coffee may be stored for several years. The moisture content of the dried bean ranges from 12½ to 13 percent.

Coffee processing does not involve curing or any chemical change in the coffee bean itself. Any change in the bean, either by bacterial action or other agents, is detrimental to the quality of the coffee. There is no treatment known that will improve the coffee (10). Hence it is imperative that the processing, including drying, be completed in as short a time as possible to reduce the chances of the coffee being subjected to action by various external agents.

Coffee beans may be dehydrated either in the cherry state or after the pulp and the mucilage are removed. Drying whole cherry is time-consuming and generally results in poorer coffee; and it is difficult to accomplish when atmospheric humidity is high. The sugars, pectins, and other materials in the pulp and mucilage are hygroscopic, hence these materials must be decomposed before the cherry will dry. Normally, enzymes naturally present in the coffee cherry (10) and microorganisms decompose the mucilaginous matter. Under humid conditions decomposition may continue beyond the required degree and undesirable decomposition products may be formed. A method has been devised whereby the cherry is treated with either pectic enzymes or a combination of these enzymes and a preparation containing cellulases, hemicellulases, and gummasess to accelerate the digestion of the mucilaginous matter before drying (9).

Drying whole cherry is usually done only in regions where low atmospheric humidity prevails during the coffee harvesting season, as in Brazil. Even there, however, much coffee is ruined when unseasonal rains occur.

Coffee processed by drying whole cherry is called "natural coffee" and usually commands a lower market price* than coffee processed by the wet method described below.

In the wet method, the pulp and mucilage are removed before drying. The bean, however, is still encased in the parchment and silver skin. Pulped and deslimed beans can be dried more rapidly than whole cherry because the pulp, which is 80 percent moisture (6), and the mucilage, which is highly hygroscopic, are removed. The present discussion is concerned with the removal of this mucilage.

Mucilage on the Coffee Bean

The mesocarp, composed of parenchyma cells, is variously called mucilage, slime, honey (5), pectic-gel (1), saccharine matter (12), lees (7, 13), residual pulp (7), mucous integument (2), etc. It is described as gummy or slimy. Mucilage is the preferred term.

The mucilage adheres tightly to the parchment and cannot be freed by simple washing or by centrifuging. It has a large water-holding capacity (10). This property can be deduced from the great reduction in volume of mucilage when freshly pulped coffee is dried under artificial heat. The dried mucilage is very hygroscopic and becomes sticky when the bean is removed from the drying oven. It absorbs moisture from the air so rapidly that artificially dried mucilage-covered beans cannot be weighed even on a torsion balance unless the bean is confined in an airtight container.

Thus it becomes evident that the mucilage must be removed or decomposed before the bean can be dried. In the dry method the enzymes naturally present in the coffee (10) and microorganisms break down the mucilage. This breakdown can be hastened by artificially adding pectic and other enzymes to the cherry (9) as pointed out above. In the wet method the mucilage is removed from the pulped beans before drying.

DEMUCILAGING

There are four general methods used today to remove the mucilage from pulped coffee beans. These are natural fermentation, artificial enzyme digestion, alkali hydrolysis, and mechanical demucilaging in which the mucilage is rubbed off by friction or high-pressure water jets.

Natural Fermentation

This is the most widely used method and the only method used commercially for demucilaging coffee until recent times. In this method the pulped coffee bean is placed in vats with or without additional water, and

*One exception occurred for a short time immediately after the 1953 frost in Brazil.

the mucilage is allowed to ferment spontaneously by means of the natural enzyme present in the coffee bean; and, also, by means of enzymes produced by bacteria, molds, and yeast which occur naturally. The process requires from 10 to 100 hours (5) depending upon the conditions.* The speed of fermentation depends upon the temperature and the concentrations of the mucilage and microorganisms. Hence, fermentation is accelerated if no additional water is added to the pulped beans and optimum temperatures for bacterial activity are maintained.

Fermentation is an exacting process. Since the mucilage contains carbohydrates and proteins, and various types of microorganisms are involved, different types of fermentation can be occurring simultaneously. The first fermentation which occurs is an alcoholic one in which the carbohydrates are converted into alcohols (5). This is followed by acetic fermentation. The latter can be retarded by keeping the fermentation temperatures low; however, low temperatures also retard alcoholic fermentation. Since the mucilage also contains proteins, putrefaction may also take place. Putrefaction is accelerated by high temperatures.

In fermenting the mucilage, it is imperative that the process be stopped when the alcoholic fermentation has progressed sufficiently to loosen the mucilage from the parchment. If the fermentation is allowed to continue, there is danger of acetic fermentation and putrefaction progressing too far. Products of these processes will be absorbed by the coffee bean, resulting in "sour beans" and beans with foul odors.

In some practices the depulped coffee is placed in a large volume of water. The water is changed from time to time. Under such conditions, the temperature does not rise to the point where acetic fermentation begins, since acetic fermentation takes place at a higher temperature than alcoholic fermentation. However, the alcoholic fermentation is also retarded considerably by the low temperature, high dispersal of microorganisms, and high dilution of nutrients. Fermentation under such conditions is safer as far as the coffee is concerned, but it takes from 72 (3) to 100 hours (5) for the mucilage to break down completely. Such prolonged processes increase the cost of processing coffee.

As has been shown above, the fermentation process is exacting and involves risks of quality deterioration. It also requires considerable outlay of space and equipment for fermentation vats. This becomes especially expensive where slow fermentation methods are used.

Another consideration, which became apparent after quick demucilaging methods were developed, is the loss in weight the coffee undergoes during the fermentation. It is well known that plant tissue respires as long as it is alive. The respiration rate is directly proportional to the temperature within certain limits. It is generally most rapid when the moisture content of the tissue is highest. In coffee beans, the respiration is most rapid immediately after pulping (11). Hence, the most active respiration takes place during the fermentation process.

*One processor in Hawaii completes the natural fermentation in three hours.

In the respiration process, the carbohydrates and other organic matter are converted to carbon dioxide which is lost to the atmosphere. Thus, as long as the respiration continues, the coffee bean is losing weight.

Jones and Bayer (11) found that coffee processed without natural fermentation weighed as much as 3.9 percent heavier than coffee dried after natural fermentation. Bannell (1) estimates that the average savings in weight would be about 3 percent if fermentation is eliminated.

Several schemes have been devised to demucilage beans, avoiding uncontrolled elements, that is, naturally occurring enzymes and micro-organisms.

All of the methods devised reduce the time of demucilaging. The alkali hydrolysis and mechanical methods described below permit the demucilaging to be carried out in a continuous operation synchronized with the pulping. The cherry enters the pulper and the bean emerges from the demucilaging device ready for drying.

The quality of the coffee demucilaged without fermentation has been proven equal or superior to coffee processed with fermentation (4, 11, 14). This does not imply that quick demucilaging will improve the quality, but it will eliminate the likelihood of fermentation products spoiling the quality.

Enzyme Digestion

One of the first methods devised to eliminate fermentation and one which has attained some popularity is that which employs enzymes.

Pectic enzymes when added to the pulped coffee will hasten the breakdown of the mucilage. One commercial product is now being manufactured for this purpose.*

It is claimed (10) that the mucilage can be decomposed in less than an hour when this commercial preparation is stirred into the fermentation vat at the rate of 0.2 percent of the pulped bean and the temperature maintained at 75° to 85°F. However, on account of the high cost of the enzyme preparation, a 0.025 percent concentration is recommended in actual practice. This will prolong the digestion time to 5 to 10 hours depending upon the temperature maintained.

Although this method provides some measure of control, it still requires fermentation vats which occupy considerable space on large plantations. Since coffee harvested during the day is normally pulped during the same afternoon and evening, the 5- to 10-hour digestion time necessitates washing during the night. From the labor standpoint, the natural fermentation, which is usually completed in 12 to 16 hours, is more convenient as the washing need not be done until the following day.

Alkali Hydrolysis

Dilute solutions of strong alkali, caustic soda or caustic potash, have been used to clean pulpy seeds such as the tomato seed. The method was not applied to coffee until about 1952.

*Sold under the trade name "Benefax."

In this method the freshly pulped coffee bean is agitated in a solution of caustic soda. Shuhart used a 6 percent solution (14) while Jones and Bayer used a 2 percent solution (11). Jones and Bayer also used wood ash and lime. In tests run at the Kona Branch Experiment Station, hand-stirring a mixture of one volume of a 2 percent sodium hydroxide solution with an equal volume of freshly picked and pulped coffee did not result in complete mucilage breakdown. However, when a 6 percent solution was used, the mucilage breakdown occurred in about one minute. The resulting bean can then be washed clean of the mucilage.

The parchment of the bean treated with the 6 percent sodium hydroxide solution was dark yellow; however, the green bean itself was normal in appearance. Shuhart (14) has already reported that the cupping quality of the alkali-demucilaged coffee was superior to fermented coffee. Germination tests conducted at the Kona Branch Station proved that the 6 percent sodium hydroxide treatment did not impair the viability of the seed.

Mechanical Devices

The enzyme digestion and alkali treatment not only require the purchase of the material but also require precise adjustments of the strengths of the respective solutions in order to achieve the most economic use of the material. The strong alkali used is also corrosive and requires careful handling. Hence, these methods are not ideal for small farms even if the cost of the material were nominal.

It has been known for many years that the mucilage on the coffee bean can be removed mechanically and several such devices have been developed.

Urgelles Device

Patent was granted for this device in 1912 (15). In this device, sand or sawdust is first imbedded into the mucilage layer of the freshly pulped bean. The bean is then subjected to rubbing action. The mucilage removal is accomplished by the abrasive action of the sand or sawdust. This machine is complicated; it involves imbedding the abrasive on the two sides of the bean, rubbing off the mucilage, and separating the abrasive and mucilage from the bean.

Birnie Pulper and Demucilaging Machine

Patent for this machine was granted in 1929 (2). This machine consists of two concentric cylinders mounted horizontally on a common shaft. The outer cylinder is stationary while the inner cylinder rotates. The inner cylinder is ribbed to increase friction. Coffee cherry or pulped coffee is forced into the space between the two cylinders by the screw action of a feeding worm.

This machine may be used to remove both the pulp and the mucilage in one continuous operation, or to remove mucilage of prepulped beans. As the inner cylinder rotates, the cherry is forced through the space between the two cylinders. The cherry is first crushed and the pulp rubbed off the

bean. As the rubbing continues, the mucilage is also removed. The pulp is broken into small pieces during the rubbing process. During the process, water is forced into the inner cylinder through the hollow spindle. This water escapes into the space between the two cylinders through small holes provided for this purpose in the inner cylinder. The pulp and mucilage are then carried by this water through holes provided in the outer cylinder. The bean is forced toward the outlet end of the device by pressure from the incoming beans. Hence the machine must be fully charged (with beans) at all times. The beans remaining in the machine after each run will not be completely demucilaged.

This machine is now manufactured commercially and is sold under various trade names.* The chief disadvantage of this machine is its high power requirement. A machine having a capacity of 3,300 pounds cherry per hour requires 14 h.p., according to specifications in one catalogue.

High-pressure Water Jet Device

A patent for this device was granted to Pellas and Kraut in 1941 (13). According to the inventor, a fluid pressure up to 300 p.s.i. is "desirable" to demucilage some "types of berries" although 100 p.s.i. is satisfactory under ordinary conditions. Such a machine obviously requires considerable amounts of water and is not suitable for localities where water supply is limited. It also requires high water head or considerable power to develop such high pressures.

Hess Coffee Washer

In 1955, a patent was granted to H. L. Hess for a demucilaging machine (7). This machine consists of several square compartments arranged in series. The compartments have a common floor which moves back and forth along the line of the compartments. A baffle plate is welded to the floor of each compartment.

Pulped coffee is fed into one end-compartment. As the baffle moves back and forth, the mass of beans is also rocked back and forth, causing the beans to rub against each other and also against the walls of the compartment. Provisions are made for the beans to move from this end-compartment into the next, and so on. The beans receive the same treatment in each compartment. Water is sprinkled over the beans and the freed mucilage allowed to drop through holes provided in the floor.

As the coffee moves from one compartment to the other it becomes cleaner, and when the machine is properly adjusted, the coffee emerges from the end-compartment completely freed of the mucilage.

Although this machine does a good job of demucilaging the coffee bean, the reciprocal action of the principal moving part requires rigid construc-

*E. H. Bental & Co. of Essex, England, is marketing a unit called "Aquapulpa." Henschell Maschinenbau of Hamburg, Germany, is manufacturing one called the "Raoeng-Pulper."

tion and extra power merely to overcome the kinetic energy of the moving part. Such a device must necessarily be of heavy construction and must be anchored to a solid foundation or suspended on special mountings in order to prevent the transmission of the heavy vibrations.

THE H.A.E.S. DEMUCILAGING MACHINE

Mechanical demucilaging of coffee beans has been under consideration at the Hawaii Agricultural Experiment Station since 1953. Centrifuging was first tried, but the mucilage adhered to the bean so tightly that it could not be removed in ordinary centrifuges. Rubbing a batch of beans by hand did remove the mucilage but the operation was too slow and too tiring. Beating a batch of beans with a rotary eggbeater was also tried, but the beans stuck between the blades. However, when a batch of pulped beans was beaten with only one set of rotating blades of a household food mixer at high speed, the beans were completely demucilaged in about 3 minutes. Several batches of beans were demucilaged in this manner, washed, sun-dried, and milled to remove the parchment cover. No physical damage to the green bean was noticeable upon close examination.

In order to make the operation continuous, a gravity feed apparatus was devised. This feeding is unique among coffee demucilaging devices so far developed. In all the devices mentioned above, the coffee is forced horizontally through the devices by mechanical force.

The apparatus developed here is essentially a "U" tube. Any liquid poured into one arm of the "U" tube will rise to a corresponding height in the other arm. Since the specific gravity of freshly pulped coffee beans is only slightly greater than that of water, water movement through the tubes will carry the beans with it provided the water flow is not too slow.

Figures 2 and 4 show a cutaway diagram of the demucilaging machine. Tube A (fig. 2) is the feeder arm into which coffee and water are funnelled simultaneously. This tube is made slightly longer than tube B. Tube B, the mixer tube, encloses a rotary beater similar in principle to the beater in a household food mixer, except that only one set of blades is used. The mixer tube is long enough to entirely enclose the beater blades with an inch of space between the top of the beater and the spout S. If the beater is exposed at the spout, there will be considerable splashing during the operation.

The beater blades are $\frac{1}{4}$ -inch steel rods welded to a $\frac{3}{4}$ -inch steel shaft, as shown in figure 2. The width of the blades is such that there is a 1-inch clearance between the outer edges of the blades and the wall of the mixer tube. Several tie-rods are welded between the blades and the shaft to prevent the blades from spreading out by centrifugal action during the operation. These rods also increase the rubbing surface of the beater.

The beater is mounted in the center of the mixer tube. It may be mounted with two ball bearings above the tube as shown in figure 2, or with one bearing above and another at the bottom of the tube as shown in figure 4. The former system of mounting requires a perfectly balanced

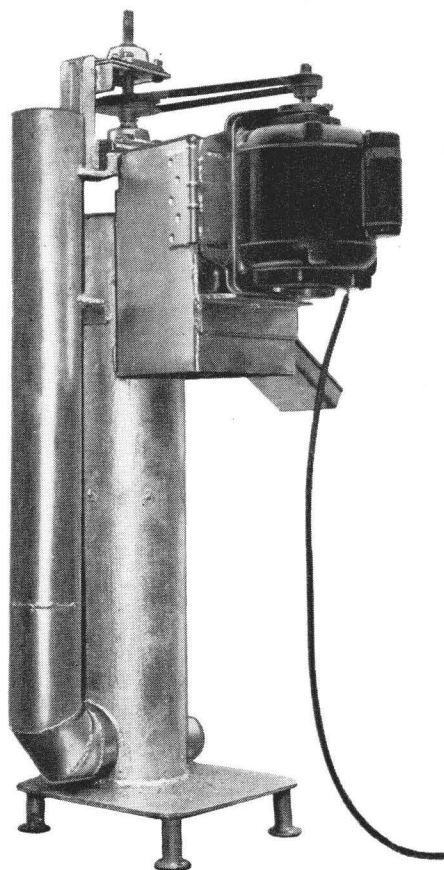


Figure 1. Single unit demucilaging machine.

beater, but lubrication becomes simpler and ordinary ball bearings may be used. If a bearing is to be used at the bottom of the mixer tube, special water-lubricating bearings or sealed bearings should be used there.

Power for rotating the beater is from an electric motor mounted as shown in figure 1 via appropriate pulleys and belt.

Several $\frac{3}{8}$ -inch steel rods are welded on the inside surface of the mixer tube. These rods act as ribs to induce stirring action. The rods are arranged in a slight spiral form in such a direction as to give the swirling mass inside the tube a slight upward thrust. However, the machine will work even if the rods are welded straight up and down.

Operation

After the blades are set in motion, freshly pulped coffee direct from the pulper, together with a constant flow of water regulated by a gate valve, is

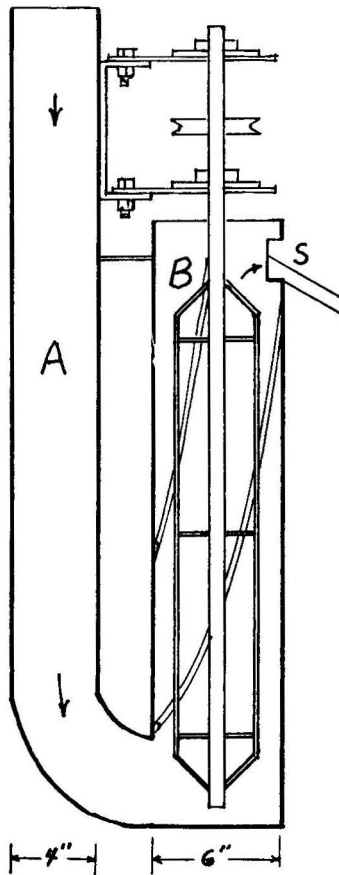


Figure 2. Cutaway diagram of coffee demucilaging machine.

funnelled into the feeder tube. As the coffee suspension rises in this tube, it also rises in the mixer tube. While the suspension is traveling up the mixer tube, the mucilage is beaten off by the rapidly moving blades of the beater.

The rate of travel of the suspension through the tubes will depend essentially upon the rate of water fed into the feeder tube. The amount of coffee fed into the feeder tube has less effect on the flow. If coffee is fed too rapidly in comparison to the water, it will pile up in the feeder tube and the hopper attached to this tube. If water is fed too rapidly into the feeder tube the coffee will travel through the tubes too rapidly, resulting in incomplete mucilage removal. Hence the regulation of the water flow is very important.

The demucilaged coffee spilling out of the spout (fig. 2, S) is then conveyed or flumed to a shaker with a screen bottom where the mucilage and excess water are shaken off. Fresh water sprinkled on the coffee beans on

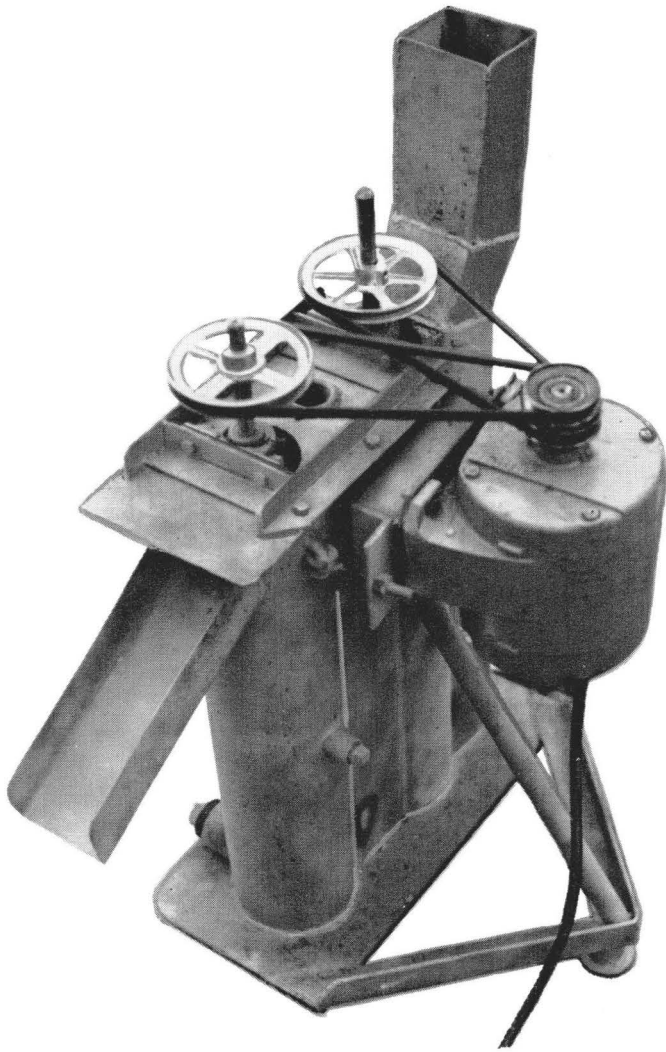


Figure 3. Tandem unit. Power is obtained from one motor.

the shaker will further wash off any mucilage adhering to the beans. The standard shaker now used on coffee farms in Hawaii may be used. These shakers are so arranged that the coffee travels directly to the drying platform while being shaken. The coffee is then ready for drying.

The machine is easily cleaned. After the pulping is completed and no more coffee is fed into the demucilaging machine, the operation is continued for a few minutes with only water being fed into the feeder tube. When coffee beans stop coming out of the outlet spout, there will be very little coffee left in the machine. The operation is then stopped and the tubes are

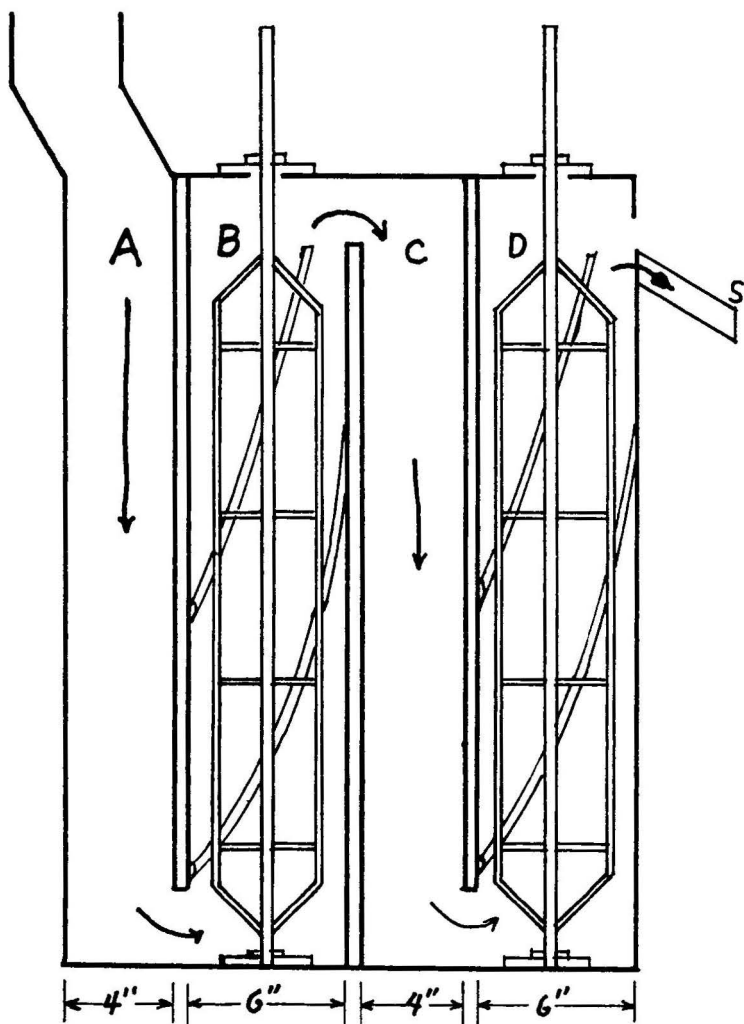


Figure 4. Cutaway diagram of two demucilaging units in a series.

drained through a bung provided at the bottom of the mixer tube onto a screen to catch any coffee beans still left in the machine.

Capacity

The capacity of the machine depends upon the diameter and length of the mixer tube and the speed of rotation of the beaters. To double the length of the tubes (feeder and mixer), two sets of tubes may be connected in tandem as shown in figures 3 and 4. This will make the machine more compact and easier to mount. In this arrangement (see fig. 4) the coffee

suspension is fed into tube A. The suspension then rises in tube B, spills into tube C, and rises through tube D.

The mass of pulped beans must be subjected to the rapid stirring action of the beater blades for a definite length of time depending upon the peripheral velocity of the blades. The greater the velocity of the blades passing through the coffee mass, the faster will be the demucilaging.

The peripheral velocity of the beater is directly proportional to the speed of rotation (r.p.m.) and the peripheral diameter. Hence, in order to maintain a constant peripheral velocity, the rotation speed must be varied inversely to the peripheral diameter for different size beaters.

Since the coffee must be in the apparatus for a definite length of time for a given peripheral velocity of the beater, either the diameter or the length of the mixer tube must be varied in order to change the capacity.

The first experimental model consisted of a 4-inch (inside dimension) mixer tube enclosing a 4-blade beater, 12 inches in length and 2 inches in peripheral diameter. The mixer tube extended 3 inches below and 4 inches above the beater. The speed of rotation was set at motor speed (1725 r.p.m.). The feeder tube was 3 inches in diameter and equipped with a funnel to facilitate feeding. Freshly pulped coffee was fed by hand. Water was piped into the feeder tube through a rubber hose. After several lots were run, the capacity was estimated at approximately 5 bags cherry per hour.

When the mixer tube was enlarged to 6 inches in diameter and the beater enlarged to 4 inches in peripheral diameter by 24 inches in length, and rotated at approximately 860 r.p.m., the capacity was doubled. When the speed of rotation of the beater was increased, more coffee could be demucilaged in a given time, but it was found that a considerable number of coffee beans emerged naked, i.e., with their parchment cover completely removed. However, it became evident later that the parchment removal was caused by rough edges on the beater and ribs in the tube. These rough edges were formed in the welding process. In a subsequent model it was found that the speed of rotation could be increased without causing any increase in naked-bean output after the demucilaging machine had been in use for some time.

In order to increase the capacity of the apparatus, two 6-inch \times 24-inch (effective length, i.e., the length of the beaters) units were connected in tandem as shown in figures 3 and 4. This in essence has the same effect as doubling the length of the beater. The coffee presumably could be passed through the machine twice as fast with the same degree of effectiveness. Tests have borne out this fact. However, a capacity of 20 bags cherry per hour was still insufficient since most pulpers used on coffee farms in Hawaii have capacities of approximately 30 bags cherry per hour.

The machine was run at a beater speed of 860 r.p.m. until about 150 bags of cherry were run through it, then the speed of rotation of both beaters was increased. The r.p.m. of the first beater (in tube B, fig. 4) was raised to approximately 1000, and that of the second (in tube D, fig. 4) to

1200. Surprisingly, the percentage of naked-bean output did not increase. This is attributed to the wearing-down of the jagged spots on the beater and the ribs inside the mixer tube. At these speeds of rotation, it was found that the pulper to which the machine was connected could be operated at its maximum capacity. Timing studies showed that the pulper was pulping 2,900 pounds of cherry per hour. This was the maximum capacity of the pulper used, and in no way established the maximum capacity of the demucilaging machine. However, from observations it could reasonably be assumed that the demucilaging machine could at least demucilage coffee emerging from a pulper pulping 3,000 pounds (30 bags) of cherry per hour.

Water Requirement

Since, as pointed out above, the rate of flow of water regulates the rate of flow of the coffee beans through the demucilaging machine, the regulation of water flow depends upon the flow rate which will give complete demucilaging and at the same time prevent coffee pile-up in the feeder tube. This is done by varying the water flow into the feeder tube while the coffee is being fed from the pulper until coffee bean pile-up in the feeder tube is noticed. At this point the water flow is increased slightly so that coffee pile-up in the feeder tube is barely prevented. If the coffee emerges from the machine incompletely demucilaged, either the pulping rate must be reduced or the speed of revolution of the beaters increased. If the coffee emerges completely demucilaged, the water flow may be increased as long as the coffee emerges satisfactorily demucilaged. Excess water is not entirely wasted since the more water used in the machine the less viscous the mucilage will be when it is discharged, and the subsequent washing operation will be easier. Excess water will insure no coffee pile-up in the feeder tube.

Measurements have shown that the minimum water flow necessary for the demucilaging machine described above is approximately 0.8 gallons (3100 ml.) per minute. Under normal operation 1-1.5 gallons per minute is being used for demucilaging coffee emerging from the pulper pulping 2,900 pounds of cherry per hour. Since the coffee is being demucilaged satisfactorily even with this excess water flow, it is evident that the machine is not being run at maximum capacity and it can at least take care of pulpers pulping at 3,000 pounds of cherry per hour.

Considerably more water is needed to wash the mucilage off the bean after it emerges from the demucilaging machine. Here the amount will depend upon the type and efficiency of the washing device. At the Kona Branch Experiment Station the coffee emerges from the demucilaging machine onto a shaker where excess mucilage is shaken off and water is sprinkled over the coffee as it moves along the shaker.

Power Requirement

A 2 h.p. motor is sufficient to operate the tandem machine (figs. 3 and 4) with beaters rotating at 1000 and 1200 r.p.m. in the first and second mixer

tubes, respectively, and demucilaging at the rate equivalent to 3,000 pounds cherry per hour.

Beaters

Several types of beaters have been tried. Four- and six-bladed beaters of the types shown in figure 4 were equally satisfactory. It was found that the tie-rods radiating from the shaft and welded to the blade to prevent the blades from bulging were also effective. More tie-rods produced better demucilaging. However, it should be remembered that there must be a limit to the number of tie-rods that can be used, since if the rods are spaced too close together they would in essence act as solid paddles which merely would cause the bean mass to rotate within the mixer tube. The ideal situation is obtained when the beater blades are moving in a bean mass which is slowly moving from the bottom of the mixer tube to the top without any rotary movement. However, this is impossible with the present design; therefore, the beater must be designed to create a minimum circular movement of the bean mass, yet afford maximum friction. Thus it is evident that the ribs on the sides of the mixer tube are also important. Tie-rods on the beaters used are 2 inches apart.

When flat steel $3/16'' \times 3/4''$ was used for the blades, the naked-bean output was increased. This is probably due to the sharp corners on the flat metal.

Beaters consisting only of spokes radiating from the center shaft were also tried. The spokes were merely steel rods welded to the shaft. In order to obtain symmetry the ends of the spokes were ground while the beater was turned on a lathe. When this beater was used not only naked-bean output was increased, but many coffee beans were damaged. The sharp edges at the ends of the spokes actually cut into the beans. However, after coarse gravel containing pebbles the size of coffee beans was run through the machine for several hours, the machine became usable. The beans emerged undamaged and the naked-bean output was reduced to negligible proportions. This machine is now being used regularly on one farm.

In one machine, blades shaped to act both as scoops and propeller were attached to the bottom of the beater shaft. This attachment made it possible to use less water, but this is no advantage, since using less water will make the mucilage more viscous, thus making it harder to wash the mucilage off with the type of washing device used here. More power is also necessary because of the high viscosity of the mucilage.

The beater blades should not extend below the top of the port leading from the feeder tube into the mixer tube. In one experimental model where the blades extended almost to the bottom of the mixer tube, the bean flow from the feeder tube into the mixer tube was reduced markedly. When the beater was rotated at 1000 r.p.m. the bean flow was practically stopped.

Naked Beans

The term naked beans is used here to denote coffee beans which have their parchment cover removed before drying. Parchment removal may

take place either in the pulper or the demucilaging device. Immature beans are more liable to become naked as the parchment has not toughened sufficiently. Naked beans emerging from the pulper are most apt to be immature. Naked beans emerging from the demucilaging machine may also include mature beans.

When naked beans are subjected to fermentation, the beans usually turn yellowish to brownish depending upon the degree of fermentation. These discolored beans down-grade the coffee, since the appearance of coffee is one of the criteria for grading it.

In tests run independently at the Kona Branch Experiment Station and on a commercial farm, it was found that naked beans emerging from demucilaging machines did not change color when they were segregated, washed, and dried immediately. When bean lots processed with mechanical demucilaging machines without fermentation were milled after drying, the naked beans could not be distinguished from the normal beans.

Damaged Beans

Coffee beans often get scratched, nicked, or broken in the pulper. Such damage may be caused by faulty pulpers or when overripe cherries are forced through the pulper. When cherries pass the dark-red stage and approach the "raisin stage" (cherries beginning to dry on the tree) the mucilage in the bean is decomposed. Since ordinary pulpers are designed to utilize the lubricating action of the mucilage for slipping the beans through the pulper, beans without mucilage move through the pulpers with difficulty. These beans become lodged in the grooves of the pulper and become damaged.

When damaged beans are subjected to fermentation, the fermentation liquors enter the bean through the openings and are absorbed by the beans. These liquors produce pronounced discolorations and impart a "sour" odor to the bean.

However, when the beans are not subjected to fermentation, discoloration does not take place if they are thoroughly washed after demucilaging. If the washing after demucilaging is not thorough, the wounds on the beans will be stained by the mucilage adhering to the surface of the wounds, but the discoloration does not soak into the bean. Damaged beans in green coffee processed by mechanical demucilaging do not stand out as in coffee demucilaged by fermentation. They also do not have the "sour" odor characteristic of damaged beans subjected to fermentation.

SUMMARY

Coffee cherry is described, followed by a brief discussion of the various steps involved in the complete processing from cherry to green coffee.

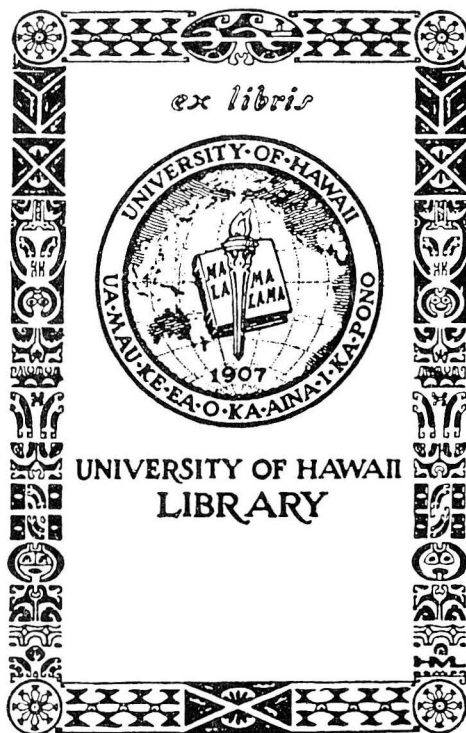
Fermentation, since it is the method used most widely for demucilaging coffee beans, is discussed at some length, together with some of its drawbacks.

Enzyme digestion, alkali hydrolysis, and mechanical methods are discussed. Several different types of mechanical devices used for demucilaging coffee are briefly discussed.

The H.A.E.S. coffee demucilaging machine developed at the Kona Branch of the Hawaii Agricultural Experiment Station, which eliminates most of the shortcomings of the different mechanical devices developed to date, is described. This machine is compact, simple to construct, and requires considerably less power than any of the other mechanical devices described herein. A machine capable of demucilaging coffee beans at a rate equivalent to 3,000 pounds of cherry per hour is described in detail.

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